(19) Japanese Patent Office (JP)

(12) Publication of unexamined patent applications (A)

(11) Publication Number of Patent Application

Japanese Patent Laid-Open No. 2003-45676

(43) Laid Open Date: February 14, 2003

(51) Int. Cl.[7]	Identification Number	FI	Theme code (reference)
H 05 B 33/28		H 05B 33/28	3K007
	33/12	33/12	C
	33/14	33/14	A
	33/22	33/22	B
			D

Request for Examination: not required

The Number of Claims: 16 OL (11 pages in total)

(21) Application Number: 2001-225847

(22) Application Date: July 26, 2001

(71) Applicant: 501231510

Kido Junji

3-12-16 Rinsengi Yonezawa-city, Yamagata

(71) Applicant: 593191350

International Manufacturing & Engineering Services Co., Ltd.

3 Kirihara Fuzisawa-city, Kanagawa

(72) Inventor: Kido Junji

9-4-3 Mamikita Kouryoucho Kitakatsuragi-gun Nara

(74) Agent: 100083286

Patent Attorney Kunio Miura

Continued on the last page

(54) [Title of the Invention]

ORGANIC ELECTROLUMINESCENT ELEMENT

(57)

[ABSTRACT]

(Object) To provide an organic electroluminescent element achieving emission at high brightness and having a long life.

(Means) The organic electroluminescent element has a plurality of light emitting units 3-1, 3-2.... and 3-n between an anode 2 and a cathode 5 which are opposite to each other, with the light emitting units separated from one another by layers 4-1,4-2...and 4-n each of which forms one equipotential surface.

[CLAIMS]

[Claim 1] An organic electroluminescent element characterized in that a plurality of

light emitting units are formed between an anode and a cathode which are opposite to each other, and the light emitting units are separated from one another by layers each of which forms an equipotential surface.

[Claim 2] In the element as set forth in Claim 1, an organic electroluminescent element in which a layer forming an equipotential surface is formed of a transparent conductive material of which transmittance of visible light is 50% or more.

[Claim 3] In the element as set forth in Claim 1, an organic electroluminescent element in which a layer forming an equipotential surface is formed of a metal or an alloy of which transmittance of visible light is 50% or more with a film thickness of 10 nm or less.

[Claim 4] In the element as set forth in Claim 1, an organic electroluminescent element in which a layer forming an equipotential surface is formed of an organic material.

[Claim 5] In the element as set forth in Claim 1, an organic electroluminescent element in which a light emitting unit includes an electron injection layer, as a layer which is in contact with an anode side of an equipotential surface, formed of a mixed layer of an organic compound and a metal serving as electro-donicity dopant.

[Claim 6] In the element as set forth in Claim 5, an organic electroluminescent element in which the electro-donicity dopant is formed of one or more kinds of metals selected from an alkali metal, an alkali earth metal, and a rare-earth metal with a work function of 4.2eV or less.

[Claim 7] In the element as set forth in Claim 5 and Claim 6, an organic electroluminescent element in which mol ratio of an electro-donicity dopant metal in an electron injection layer is 0.1 to 10 to an organic compound.

[Claim 8] In the element as set forth in Claim 1, an organic electroluminescent element

in which light emitting unit includes an electron injection layer, as a layer which is in contact with an anode side of an equipotential surface, formed of a metal selected from an alkali metal, an alkali earth metal, or a rare-earth metal with a film thickness of 5 nm or less.

[Claim 9] In the element as set forth in Claim 1, an organic electroluminescent element in which light emitting unit includes an electron injection layer, as a layer which is in contact with an anode side of an equipotential surface, formed of a metal obtained by reducing a metal ion contained in an organic metal-complex compound including at least one kind of an alkali metal, an alkali earth metal, and a rare-earth metal by using a metal which can reduce the metal ion to a metal, and an organic compound.

[Claim 10] In the element as set forth in Claim 1, an organic electroluminescent element in which a light emitting unit includes a hole injection layer, as a layer which is in contact with a cathode side of an equipotential surface, formed of a mixture of an organic compound and an electron-accepting compound having a property of oxidizing the organic material Lewis-acid-chemically.

[Claim 11] In the element as set forth in Claim 10, an organic electroluminescent element in which a mol ratio of an electron-accepting compound having a property of oxidizing an organic material in an hole injection layer Lewis-acid-chemically is 0.1 to 10 to an organic compound.

[Claim 12] In the element as set forth in Claim 1, an organic electroluminescent element in which a light emitting unit includes a hole injection layer, as a layer which is in contact with a cathode side of an equipotential surface, formed of an electron accepting compound with a film thickness of 30 nm or less.

[Claim 13] In the element as set forth in any one of Claim 10 to Claim 12, an organic

electroluminescent element in which an electron-accepting compound is an inorganic Lewis acid compound or an organic compound.

[Claim 14] In the element as set forth in Claim 1, an organic electroluminescent element in which a plurality of light emitting units have light emitting spectrums each of which is different from one another.

[Claim 15] In the element as set forth in Claim 1, an organic electroluminescent element in which a luminous color is white according to the superposition of luminescence from each light emitting unit.

[Claim 16] In the element as set forth in Claim 1, an organic electroluminescent element in which at least one of light emitting units in a plurality of the light emitting units includes a phosphorescence light emitting material.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an organic electroluminescent element (hereinafter, referred to as an organic EL element for short) used for a flat surface light source and a display element.

[0002]

[Description of the Prior Art]

An organic EL element having a light emitting layer formed of an organic compound between an anode and a cathode which are opposite to each other has attracted attention in recent years as an element for realizing a large area display device of a low-voltage drive. Tang et al. has succeeded in obtaining an organic electroluminescent layer achieving emission at high brightness and having high-efficiency which is enough for a practical use with 1000 cd/ m^2 and external

quantum efficiency of 1% by being applied with voltage of 10V or less, by applying a structure of laminating organic EL compounds which are different one another in carrier transport properties and injecting holes and electrons from an anode and a cathode in a balanced-manner and setting the film thickness of the organic layer at 2000Å or less (Appl. Phys. Lett. , 51,913 (1987). However the conventional organic EL element only achieves the half life of more than ten thousand hours with luminance of approximately 100 cd/m^2 which is required for the use of the display or the like in terms of element life. Obtaining the element life required practically with luminance of approximately 1000 cd/m^2 to approximately 10000 cd/m^2 which is required for the use of lighting or the like remains to be difficult at present and such a high luminance and long life-organic EL element has not yet realized actually.

[0003]

[Problem to be solved by the invention]

The invention has been made in view of the aforementioned situation, and it is an object of the invention to provide an element structure in which long life and high luminance luminescence are realized, which has been difficult to be achieved in the conventional organic EL element.

[0004]

[Means for Solving the Problem]

As a result of the earnest research to solve the above problems, the present inventor has completed the invention by applying a structure of laminating a plurality of light emitting units to be separated from one another by layers each of which forms an equipotential surface between an anode and a cathode which are opposite to each other. According to the structure, in the element, when predetermined voltage is applied

between both electrodes, each light emitting unit is connected in series, and emits light simultaneously, and then high current efficiency (or quantum efficiency), which has been impossible to be realized is found to be realized. Namely, the organic EL element of this invention is characterized in that a plurality of the light emitting units are formed between an anode and a cathode which are opposite to each other, and the light emitting units are separated from one another by layers each of which forms an equipotential surface.

[0005]

In this specification, the light emitting unit has a laminating structure including a light emitting layer composed of an organic compound, represents a part of the laminated body except an anode and a cathode in a component constituting the conventional organic EL element, and can emit light when a predetermined voltage is applied between the anode and the cathode. Further, the layer forming the equipotential surface (hereinafter it may be just referred to as an equipotential surface) mean a layer that does not have potential difference substantially in the thickness direction and the face direction when applied with voltage.

[0006]

[Embodiment of the Invention]

Next, the invention is described in detail with reference to drawings. The organic EL element of the invention includes a fundamental structure of a known organic EL element, that is an anode electrode/light emitting units (generally, a laminating structure of two or more organic layers)/a cathode electrode, and is characterized in that two or more light emitting units sandwiched between both electrodes exist and the units are separated from one another by layers each of which

forms an equipotential surface receptively. The conventional organic EL element has, as shown in FIG. 1, a structure in which a single light emitting unit is sandwiched between electrodes, an electron (e-) is injected from a cathode and a hole (h+) is injected from an anode respectively to be recombined in the light emitting unit, thereby generating an excited state to emit light. On the contrary, in the organic EL element of the invention shown in FIG. 2, electron-hole recombination is generated in a plurality of the light emitting units separated from one another by the equipotential surfaces, thereby generating plural emission of light between electrodes.

[0007]

In the organic EL element of the invention, a transparent conductive material of which transmittance of visible light is 50% or more is preferably used for the material for forming an equipotential surface. If the transmittance of the visible light is less than 50%, generated light is absorbed when it passes through the equipotential surface, and high current efficiency can not be obtained even when the plurality of light emitting units are laminated. As the transparent conductive material, for example, conductive inorganic compounds such as ITO (indium tin oxide), IZO (indium zinc oxide), SnO_2, ZnO_2, TiN, ZrN, HfN, TiOx, VOx, CuI, InN, GaN, $CuAlO_2$, $CuGaO_2$, $SrCu_2$, O_2, LaB_6, and RuO_2 are given. Further, an extremely thin metal film that can secure transparency can be used as the equipotential surface. Furthermore, lamination of a dielectric and a metal film can be used. As the example, a two-layered film such as Au/Bi_2O_3, or a multi-layer film such as $SnO_2/Ag/SnO_2$, $ZnO/Ag/ZnO$, $Bi_2O_3/Au/Bi_2O_3$, $TiO_2/TiN/TiO_2$, and $TiO_2/ZrN/TiO_2$ is known. The metal thin film or metal film in the multi-layer film having equal to or more than two layers is preferable to have a film thickness of 10 nm or less, more preferably, 0.5 nm to 10 nm. When the film thickness exceeds 10 nm,

light transmittance becomes 50% or less, and luminous efficiency is decreased.

[0008]

As the material for forming the equipotential surface, a conductive organic material can also be used. As the example, conductive fullerene such as C_{60}, a conductive organic material such as oligothiophene, metallophthalocyanine, metal-free phthalocyanine, metal porphyrin, metal-free porphyrin, or the like can be given.

[0009]

In this invention, the light emitting unit represents a component without an anode and a cathode in a component constituting the conventional organic EL element as described above. As the structure of the conventional organic EL element, for example, (anode)/light emitting layer/(cathode); (anode)/hole transporting layer/light emitting layer/(cathode); (anode)/hole transporting layer/light emitting layer/electron transporting layer/(cathode) ;(anode)/ hole injecting layer/ hole transporting layer/light emitting layer/electron transporting layer/electron injecting layer/(cathode), and the like are given. In the organic EL element of the invention, the light emitting units may have any laminated structure as long as there are a plurality (two or more) of light emitting units, which are separated one another by each equipotential surface. In addition, the materials used for the light emitting layer, the hole transporting layer, the hole injecting layer, the electron transporting layer, the electron injecting layer or the like are not specifically limited, and an known arbitrary material which has been used conventionally for these layers is used. For example, various fluorescent materials and phosphorescent materials are given.

[0010]

As the material for the cathode, a metal with low work function or alloy

including the metal, metal oxide or the like can be used generally. Specifically, a single metal element of alkali metal such as Li, alkaline earth metal such as Mg and Ca, and rare earth metal such as Eu, or alloy of these metal and Al, Ag, or In or the like can be used. Alternatively, the property of the work function or the like is not limited particularly as long as the cathode is formed of a conductive material in a structure of using a metal doped organic layer at the interface of the cathode and the organic layer (Unexamined Patent Publication No. Hei 10-270171), which has been proposed by the present inventor. Further, metal such as Al, Zr, Ti, Y, Sc, and Si, or alloy including theses metals can be used as the material for the cathode material by using a technique disclosed in Unexamined Patent Publication No. Hei 11-233262 and Unexamined Patent Publication No.2000-182774 of the present inventors. Specificity, aluminum that is widely used as the wiring electrode generally is preferably used as the wiring electrode. Alternatively, a transparent material such as ITO (indium, tin oxide) and IZO (indium, zinc oxide) can be used as the anode material, for example.

[0011]

The organic EL element of the invention including a new element structure is characterized by being greatly different from the conventional organic EL element in the following point. First, although in the convention organic EL element, upper limit of quantum efficiency that is a ratio of the number of the electrons injected into an element and the number of the photons discharged into the element is theoretically 1 (= 100%), there is no theoretical limitation in the organic EL element of the invention. This is because the hole (h+) injection shown in FIG. 2 means drawing of electrons from a molecular orbital in a ground state of an organic molecular, and the drawn electron drawn from the molecular orbital in the ground state of the layer which is in contact

with the cathode side of the equipotential surface is reused to produce a luminous excited state by being injected into the molecular orbital in the excited state of the layer which is in contact with the anode side. Therefore, the total sum of quantum efficiency of the plurality of the light emitting units separated from one another by the layer defined as an equipotential surface becomes the quantum efficiency of the organic EL element of the invention, and the value thereof does not have the upper limit. Namely, even though the organic EL element of the invention is the same as the state where a plurality of the conventional organic EL elements are connected in series by a metal conductor, as a circuit, surface luminescence is still possible similarly to the conventional organic EL element since the equipotential surface has a transparent film structure.

[0012]

Needless to say, since the organic EL element of the invention has a structure in which the plurality of conventional organic EL elements (the number of *n*) are connected in series, it is obvious that the driving voltage is equal to the total sum ($V=V_1 +V_2 +....V_n$) of potential drop volume (Vn) which is consumed by each luminous unit. Thus, it is also obvious that as the number of the luminous units(*n*) increases more and more, low drive voltage of 10V or less that has been an advantage in the conventional organic EL elements become impossible in the elements of the invention. However, the organic EL element of the invention has several advantages compared to the conventional organic EL elements. First, the brightness of the organic EL element is approximately proportional to current density so that high current density is necessarily required when high luminance is to be obtained. On the contrary, element life (not drive voltage) is inversely proportional to current density, and therefore the element life

is shortened due to high luminance luminescence. However, in the organic EL element of the invention, *n*-times luminescence can be obtained by disposing *n* luminous units each of which has the same structure between electrodes with the current density kept approximately constant. At this time, it is a matter of course that the drive voltage as mentioned above is *n* times or more, and the advantage of the realization of the high luminance of *n* times at no expense of its life is immeasurable.

[0013]

In addition, for example, in the case of using the display of a simple matrix structure as an application, the element structure of the present invention has an advantage that the decrease of the current density can largely reduce the voltage drop and temperature rise of a substrate caused due to the wiring resistance compared to the conventional case. Furthermore, high voltage in the light emitting element portion compared to the conventional element means that the degree of the voltage drop due to the wiring resistance does not have much effect on the luminance decrease. Therefore, in addition to the characteristic of the invention that voltage drop in the wiring portion is already small; it means that the display device with a simple matrix structure by constant voltage control that has not been obtained in the conventional element can be realized.

[0014]

[Embodiment]

FIG. 3 is a schematic cross-sectional sketch showing a laminated structure of an organic EL element of the invention. On a glass substrate (transparent substrate) 1, a transparent electrode 2 constituting an anode electrode, a light emitting unit 3-1, an equipotential surface 4-1, a light emitting unit 3-2, an equipotential surface 4-2, ...

an equipotential surface 4-(n-1), and a light emitting unit 3-n are repeatedly laminated in this order and a cathode electrode 5 is laminated over these layers lastly. Note that the glass substrate (transparent substrate) 1, a transparent electrode 2, a light emitting unit (3-n, n=1,2,3....), and a cathode electrode 5 are known elements in theses elements (layers), and the point that there are a plurality of the light emitting units separated from one another by each equipotential surface (4-n, note that n=1,2,3....) between the both electrodes is novel in to the organic EL element of the invention.

[0015]

It is said that work function that is one of the property of the electrode material has an influence on the characteristic of the element (drive voltage or the like) in an organic EL element. In each equipotential surface (4-n) of the organic EL element according to the invention, an electron is injected in a direction of the anode and a hole is injected in a direction of the cathode, and therefore, in the element constituting the light emitting unit above, the formation method of the electron injection (transporting) layer and a hole injection (transporting) layer are especially an important element in the case of injecting charge (electron and hole) into each light emitting unit, to decrease an energy barrier.

[0016]

In the case of injecting the electron from each equipotential surface (4-n) to an anode side, as disclosed in Unexamined Patent Publication No. Hei 10-270171, it is preferable that each light emitting unit is in contact with the anode side of the equipotential surface, and have a structure including an electron injection layer formed of a mixed layer of an organic compound and a metal serving as an electron-donating (donor) dopant. Here, the donor dopant is preferably formed with a metal selected

from one or more kinds of alkali metals, an alkaline-earth metal, and a rare earth metal, which has a work function of 4.2eV or less. The detail of these metals is described in Unexamined Patent Publication No. Hei 10-270171. The mol ratio of the donor dopant metal in the above electron injection layer is preferably 0.1 to 10 to an organic compound. When the mol ratio is lower than 0.1, the concentration of the molecule reduced by the dopant (hereinafter referred to as reduced molecule) is too low, and doping effect is small. When the mol ratio exceeds 10 times, dopant concentration in the film exceeds the concentration of the organic molecule extremely, and concentration in the film of the reduced molecule is decreased extremely, thereby reducing the doping effect. By using the light emitting unit having a structure with the electron injection layer as described above, electron injection without the energy barrier can be realized in spite of the work function of the material forming the equipotential surface.

[0017]

The light emitting units may have a structure having an electron injection layer including layers formed of a metal selected from an alkali metal, an alkali earth metal and a rare-earth metal with a film thickness of 5 nm or less, preferably, 0.2 to 5 mn as a layer in contact with an anode side of the equipotentail surface. It is not preferable that the film thickness exceeds 5 nm, since light-transmittance is reduced and excessive existence of unstable metals in air with high reactive makes the element unstable. Furthermore, the electron injection layer composed of the organic metal complex (the metal ion in the complex compound is selected from a metal with low work function such as an alkali metal, an alkali earth metal, and a rare-earth metal) and a metal which reduces the metal ion in the organic metal complex to the metal in vacuo described in Unexamined Patent Publication No. Hei 11-233262 and Unexamined Patent Publication

No. 2000-182774 may be applied, and the film thickness of the reducing metal (Al, Zr, Si, TI, or the like) which is to be used is made extremely thin to obtain the transparency of the film thickness, so as to serve as an electron injection layer.

[0018]

Alternatively, for example, in the case of injecting holes from each equipotential surface (4-n) to a cathode side, by forming a hole injection layer doped with an electron-accepting compound (Lewis acid compound) having a property of oxidizing Lewis-acid-chemically an organic material, which is suggested in Unexamined Patent Publication No. Hei 11-251067 by the inventor of this invention as layer in contact with a cathode side of the equipotential surface, hole injection without an energy barrier can be realized in spite of the work function of the material forming the equipotential surface (4-n). In addition, an electron-accepting compound layer (Lewis acid compound) which is extremely thin to obtain transparency is formed so as to serve as a hole injection layer. In this case, the film thickness is preferably 30 nm or less, more preferably ranging from 0.5 to 30 nm. It is not preferable that the film thickness exceeds 30 nm, since light-transmittance is reduced and excessive existence of unstable Lewis acid compound in air with high reactive makes the element unstable.

[0019]

The electron accepting compound (Lewis acid compound) is not specifically limited, however, for example, an inorganic compound such as ferric chloride, ferric bromide, ferric iodide, aluminum chloride, aluminum bromide, aluminum iodide, gallium chloride, gallium bromide, gallium iodide, indium chloride, indium bromide, indium iodide, antimony pentachloride, arsenic pentafluoride, and boron trifluoride or an organic compound such as DDQ (dicyano dichloroquinone), TNF(trinitrofluorenone),

TCNQ(tetracyano-quinodimethan) and 4F-TCNQ(tetra fluoro-tetracyano-quinodimethane) can be used. The mol ratio of the organic compound in the hole injection layer and the electron accepting compound is preferably in the range of 0.1 to 10 to the organic compound. When the ratio of the dopant is less than 0.1, the concentration of the molecule which is oxidized by dopant (hereinafter referred to as oxidized molecule) is too small and the effect of the doping is small. When the ratio of the dopant is more than 10 times, the concentration of the dopant greatly exceeds the organic molecule concentration in the film, and the concentration of the oxidized molecule in the film is extremely reduced, thereby reducing the doping effect.

[0020]

In the light emitting units used in this invention, the layer directly in contact with the cathode or the anode may have the same structure as a layer which is in contact with an anode side of the equipotential surface or a layer which is in contact with a cathode side of the equipotential surface, or an electron injection layer and a hole injection layer each having different composition may be used as the layer. Needless to say, an electron injection layer and a hole injection layer which are used in the conventional organic EL element can also be used.

[0021]

[Embodiment]

The invention is described in detail with reference to embodiment as below; however, the invention is not limited hereto. Note that a vacuum evaporator made by Vieetech Japan Co., Ltd., and NFTS sputtering device made by FTS Corporation are used for the film formation of the organic compound, metal, and a transparent

conductive film. The film thickness is measured by P10 of stylus profiler system made by KLA-Tecor Corporation. The characteristic evaluation of an element is carried out by Keithley Source Meter 2400 and Topcon BM-8 luminance meter. By using ITO as an anode and Al as a cathode of the element, DC voltage is applied at the ratio of 0.2V/2 sec. in a step like pattern so as to measure luminescence and current value after one second of voltage rise. EL spectacle is measured with constant current drive using PMA-11 optical multi-channel analyzer made by Hamamatsu Photonics K.K.

[0022]

A standard example (Manufacturing example of a conventional organic EL element)

The conventional organic EL element including a laminated structure shown in FIG. 4 is manufactured as below. ITO with a sheet resistance of 20Ω/□ (indium-tin oxide: sputter deposited material made by Sanyosinnku Company) is coated in a predetermined pattern over a glass substrate 1(refer to FIG. 9(a)). αNPD, shown by the following formula (1)having a hole transparency is formed thereover through an organic formation metal mask (FIG. 9b) with a film thickness of 600 Å at 2 Å /sec. deposition rate under 10^{-6} torr to form the hole transporting layer 6.

[Chemical 1]

[0023]

Then, tris (8-quinolinolato)aluminum complex (hereinafter referred to as Alq in short) and cumarin derivatives that is green color light emitting fluorochrome (trade name: NKX-1595)(made by Japan Kanko Sikiso company) shown by the following formula (2) as the light emitting layer 7, are formed over the hole transporting layer with a thickness of 400Å so that the fluorochrome has a concentration of 1 weight % by adjusting the each deposition rate.

[Chemical 2]

[0024]

Subsequently, as a metal doping electron injection layer 8 illustrated in Unexamined Patent Publication No. Hei 10-2070171, bathocuproin and cesium metal (Cs) illustrated in the following formula (3) are formed over the light emitting layer 7 with a film thickness of 300Å to have the mole ratio of 1:1 by adjusting each deposition rate.

[Chemical 3]

[0025]

Then, Al is formed with a film thickness of 1000Å at a deposition ratio of 10Å/sec as a cathode 5 through a cathode formation metal mask (refer to FIG. 9(d)). According to this step, the light emitting regions becomes a square shape of 0.2 cm on a side. DC voltage is applied between ITO serving as an anode and Al serving as a cathode, and the characteristic of the green light emitting from the light emitting layer (Alq: NKX -1595 co-evaporation layer) in the organic EL element is measured. The ○ plots in FIG. 5, 6, 7, and 8 show luminance (cd/m^2)-voltage (V) property, luminance (cd/m^2)-current density (mA/m^2) property, luminance (cd/m^2)-current efficiency (cd/A) property, and current density (mA/cm^2)-current efficiency (cd/A) property. The properties in the typical luminance value is put together in Table 1.

[0026]

[Table 1]

[0027] Embodiment 1

A light emitting unit 3-1 is formed over an ITO that is coated into a predetermined pattern shown in FIG. 9 (a) through an organic formation mask [FIG.9(b)]. Namely, a 600Å-thick αNPD, a 400Å-thick layer of Alq:NKX-1595 = 100:1, and 300Å-thick mixed layer of Bathocuproin and metal cesium (Cs) are sequentially laminated. Then, ITO is formed over the metal doped layer as an equipotential surface 4-1, with a thickness of 100Å at a formation speed of 4 Å/sec by sputtering which is proposed by the inventors in Japanese Patent Application No. 2001-142672. A metal mask (FIG. 9(c)) is used to be a square shape of 0.2 cm on a side so that the layer (equipotential surface) conforms with light emitting area. Subsequently, by using the organic formation metal mask (FIG. 9(b)) again, the aforesaid steps are repeated once again to form the light emitting unit 3-2. Namely, a 600Å-thick αNPD, a 400Å-thick layer of Alq:NKX-1595 = 100:1, and a 300Å-thick mixed layer of bathocuproin and metal cesium (Cs) are sequentially laminated. At last, Al is deposited with a thickness of 1000Å at the deposition ratio of 10Å/sec. so as to obtain the organic EL element having the pattern shown in FIG. 9(e) through the cathode formation metal mask (FIG. 9(d)) as the cathode 5. The light emitting region obtained according to the steps has a square shape of 0.2 cm on a side. A bird's-eye view of the organic EL element obtained in Embodiment 1 is shown in FIG. 11 and the laminated structure thereof is shown in FIG. 12. DC voltage is applied between ITO serving as an anode and Al serving as a cathode in the organic EL element, and the characteristic of the green light emitting obtained from the light emitting layer (Alq: NKX -1595 co-evaporation layer) are measured. The □ plots in FIG. 5, 6, 7, and 8 show luminance (cd/m^2)-voltage (V) property, luminance (cd/m^2)-current density (mA/m^2) property, luminance (cd/m^2)-current efficiency (cd/A) property, and current

density (mA/cm^2)- current efficiency (cd/A) property of the element. The main property in the typical luminance value of the element manufactured in Embodiment 1 is put together in Table 2.

[0029]

The organic EL elements including two light emitting units separated from one another by an equipotential surface shows two times current efficiency (quantum efficiency) compared to the standard example of the organic EL element with the same luminance. Although the light emitting spectrum thereof almost coincides with the fluorescence spectrum of the NKZ-1595, half-amplitude level of the spectacle is slightly thinned (refer to FIG. 10) compared to the standard example according to the observation of the light emitting spectrum. This is because light emitting from the light emitting unit 3-1 formed first in the two light emitting units is reflected by the cathode, and phases of the reflected light and the light emitting emitted directly to the substrate direction almost the same, thereby causing an interference effect.

[0030]

[Effect of the Invention]

As for the organic EL element according to the present invention, a long life element can be realized in a high luminance region that has not been able to be realized in the conventional organic EL element while keeping current density constant by arranging a plurality of light emitting units separated from one another by an equipotential surface between electrodes. When it is applied to lighting, voltage drop due to resistance of an electrode material can be suppressed and therefore uniform luminescence at a large area is possible. Further, when it is applied to the display of the simple matrix structure, voltage drop due to resistance of wiring resistance and

temperature rise of a substrate can be widely suppressed, and therefore a simple matrix display with a large area that has not been able to be realized in the conventional element can be realized.

[Brief Description of Drawings]

[FIG. 1] An explanatory drawing showing operating mechanism of a conventional organic EL element.

[FIG. 2] An explanatory drawing showing operating mechanism of an organic EL element of the present invention.

[FIG. 3] A schematic cross-sectional sketch showing a laminated structure of an organic EL element of the present invention.

[FIG. 4] A schematic cross-sectional sketch showing a laminated structure of a conventional organic EL element.

[FIG. 5] A graph showing a drive voltage - luminance property of an organic EL element manufactured in a standard example and Embodiment 1 of the present invention.

[FIG. 6] A graph showing a drive voltage - current density property of an organic EL element manufactured in a standard example and Embodiment 1 of the present invention.

[FIG. 7] A graph showing luminance - current efficiency property of an organic EL element manufactured in a standard example and Embodiment 1 of the present invention.

[FIG. 8] A graph showing a current density - current efficiency property of an organic EL element manufactured in a standard example and Embodiment 1 of the present invention.

[FIG. 9] A manufacturing flow chart of an organic EL element of the present invention.

[FIG. 10] A light emitting spectrum of an organic EL element manufactured in a standard example and Embodiment 1 of the present invention.

[FIG. 11] A bird's-eye view showing a cross-sectional structure of an organic EL element of the present invention.

[FIG. 12] A schematic cross-sectional sketch showing a laminated structure of an organic EL element manufactured in Embodiment 1.

[Explanations of the Letters of numerals]

1. transparent substrate
2. transparent anode
3-1. light emitting unit
3-2. light emitting unit
3-n. light emitting unit
4-1. equipotential surface
4-2. equipotential surface
4-n. equipotential surface
5. cathode
6. hole transporting layer
7. light emitting layer
8. electron injection layer

Continuation of the front page

(51) Int. Cl. [7] Identification Number FI Theme code (reference)

H 05 B 33/26 H 05B 33/26 A

(72) Inventor: Tokio Mizukami

International Manufacturing & Engineering Services Co., Ltd.

3 Kirihara Fuzisawa, Kanagawa